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DECLARATION

I, the undersigned, Toshiaki AKAI, c/o NEC Patent Service Ltd., of Goyou-Shibaura Building, 5-11, Shibaura 4-chome, Minato-ku, Tokyo, Japan, do hereby solemnly and sincerely declare that I am familiar with the English and Japanese languages, that I have prepared the attached English translation which is a full, true and faithful one of the patent application filed with the Patent Office of Japan under the Application No. 142491/2000 and that the present declaration is intended for use in connection with a patent application placed before the United States Patent and Trademark Office.

I further declare that all statements made herein in my own knowledge and belief are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issuing thereon.

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[Title of the Invention] Fabrication Method of Liquid Crystal Display Panel

[Claims]

[claim 1] A fabrication method of a liquid crystal display panel having a pair of opposing transparent substrates adhered each other by a seal and liquid crystal sealed in a gap between said substrates, which is surrounded by said seal, including the steps of forming said seal on said transparent substrates such that said seal surrounds a display area of said transparent substrate, arranging spacers on said display area of said substrate, dropping liquid crystal onto an area surrounded by said seal on said transparent substrates, forming a panel by sticking one of said transparent substrates on the other via said seal in a vacuum chamber, thereafter deforming said panel under atmospheric pressure by putting said panel under atmospheric pressure and, after a volume within said panel becomes equal to a volume of said liquid crystal, hardening said seal, characterized by that

said spacers have an initial size in a cell gap direction larger than an appropriate cell gap necessary to perform an appropriate liquid crystal display.

[claim 2] A fabrication method of a liquid crystal display panel, as claimed in claim 1, characterized by that spacers elastically deformable from an initial size thereof to a size corresponding to said appropriate cell gap are used as said spacers.

[claim 3] A fabrication method of a liquid crystal display panel, as claimed in claim 1, characterized by that a seal mixed with spacers formed of a material, which is hardly deformed substantially even when it is pinched between said substrates under atmospheric pressure, is used as said seal.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a fabrication method of a liquid crystal display panel having spacers dispersed on a display area thereof by using the liquid crystal falling-drop method.

[0002]

[Prior Art]

In general, a liquid crystal display panel has a structure composed of a pair of opposing transparent substrates adhered to each other by a frame-shaped seal formed on a periphery of a display area thereof and liquid crystal filling a region of a gap between the substrates, which is surrounded by the seal. Furthermore, in order to maintain a cell gap at an appropriate value, spacers (referred to as "seal spacers") mixed in the seal and spacers (referred to as "display area spacers") arranged in the display area are used.

[0003]

In view of a method for filling liquid crystal, the fabrication method of a liquid crystal display panel is classified to a liquid crystal injection method and a liquid crystal dropping method. In either of the methods, the rubbing step of printing an alignment film (polyimide film) and rubbing the alignment film to form grooves for aligning liquid crystal molecules is included after the patterning steps of an insulating film, which is necessary according to a liquid crystal display system employed, transparent electrode films, switching elements and a color filter layer, etc., which are formed on the transparent substrates. The methods are different from each other in the assembling step subsequent to the rubbing step. The difference will be described respectively.

[0004]

In the liquid crystal injection method, a liquid crystal display panel is assembled in the following manner. That is, the seal in the form of a closed curve is formed around the display area on either one of the transparent substrates by a drawing printing using a dispenser or a screen printing, etc.

And, the spacers are arranged on either one of the transparent substrates by forming or dispensing them thereon. Thereafter, one of the transparent substrates is stuck on the other and the seal is hardened after the gap between the transparent substrates is regulated to a desired value while externally pressing the substrates. In this step, it is necessary to keep a desired cell gap. Thereafter, liquid crystal is injected into the gap between the transparent substrates through an opening portion of the seal as a liquid crystal injection port by vacuum method usually. Thereafter, the liquid crystal injection port is sealed by a sealing resin. Describing the vacuum method here, it is a method for injecting liquid crystal into the liquid crystal display panel by setting the liquid crystal display panel having the liquid crystal injection port in a vacuum device, evacuating the vacuum device, dipping the liquid crystal injection port in a liquid crystal tank and then gradually increasing pressure to atmospheric pressure.

[0005]

On the other hand, in the liquid crystal falling-drop method, the liquid crystal display panel is assembled as follow. That is, the seal in the form of a closed curve is formed around the display area on either one of the transparent substrates by a drawing printing using a dispenser or a screen printing, etc. And, spacers are arranged on at least a display area of the transparent substrate by forming or dispensing them thereon. Thereafter, a suitable amount of liquid crystal is dropped onto the transparent substrate, on which the seal is provided and display area spacers are arranged. Thereafter, the transparent substrates are positioned within a vacuum chamber and one of the transparent substrates is stuck on the other. Thereafter, the transparent substrates are left under atmospheric pressure to allow the transparent substrates to be deformed by a pressure corresponding to a difference between atmospheric pressure and a negative pressure within the liquid crystal display panel to reduce the gap between

the transparent substrates. The seal is hardened at a time when a desired cell gap is obtained by such deformation of the transparent substrates.

[0006]

In either of the methods, thermosetting resin or ultraviolet ray setting resin is mainly used as a material of the seal. Further, spherical or circular pillar shaped granulous spacers are used as the seal spacers or the dispersed display area spacers. The display area spacers provided by forming means the circular pillar shaped spacers, etc., formed by patterning.

In either of the methods, finally, the substrates are cut out to form an outer configuration of the liquid crystal display panel and the liquid crystal display panel is completed by adhering polarization plates onto a front and rear surfaces thereof.

[0007]

[Problems to be Solved by the Invention]

In the fabrication method of the liquid crystal display panel using the conventional liquid crystal falling-drop method, the following problem occurs during a period from a time when the liquid crystal display panel including the mutually adhered transparent substrates is left in atmospheric condition to a time the seal is hardened.

The problem of the fabrication method of the liquid crystal display panel using the conventional liquid crystal falling-drop method will be described with reference to a TFT drive type color LCD panel as an example. (TFT: Thin Film Transistor, LCD: Liquid Crystal Display).

[0008]

FIG. 2 is a typical cross section of a liquid crystal display panel 20 fabricated by the conventional fabrication method. This liquid crystal display panel 20 is a TFT drive type color LCD panel. As shown in FIG. 2, the liquid crystal display panel 20 is constructed with mainly a TFT substrate 1, a color filter substrate 2 opposing to the TFT substrate, liquid crystal 3 pinched

between these substrates 1 and 2, a seal 4 for adhering the substrates 1 and 2 together and sealing liquid crystal 3, seal spacers 5 mixed in the seal 4 and display area spacers 16. An initial average size of the display area spacers 16 in a cell gap direction is set to a value equal to an appropriate cell gap value d0 to be achieved for appropriately performing a liquid crystal display. When the display area spacers are spherical or circular pillar shaped granulous spacers, the size thereof in the cell gap direction corresponds to a diameter thereof or, when it is a pillar shaped spacer, the size corresponds to a height thereof.

[0009]

FIG. 2(a) shows a state immediately after liquid crystal 3 is dropped onto the TFT substrate 1, on which the seal 4 is formed and the display area spacers 16 are arranged, the substrates 1 and 2 are adhered to each other within a vacuum chamber and the adhered substrates are put in atmosphere. In this state, an inside of the liquid crystal display panel 20 is a pressure (negative pressure) lower than atmospheric pressure, so that liquid crystal 3 does not fill an entire inside area of the liquid crystal display panel 20 completely as yet, leaving a vacuum portion 7. Thereafter, the liquid crystal display panel 20 is deformed due to a pressure difference between atmospheric pressure and the negative pressure within the panel in such a way that a distance between the TFT substrate 1 and the color filter substrate 2 is reduced. In FIG. 2, since the lower TFT substrate 1 is put on a horizontal plane, the color filter substrate 2 is deformed or moved. By this deformation or movement, liquid crystal 3 is pressed and gradually spread radially outward in a plane direction, reducing the vacuum portion 7 gradually.

[0010]

However, the deformation of the liquid crystal display panel 20 proceeds in a center portion at higher speed than that in a peripheral portion

as shown in FIG. 2(b). This is because, although atmospheric pressure exerted on the substrate is uniform, viscosity of liquid crystal 3 is very small compared with viscosity of the seal 4. That is, resistance force of liquid crystal 3 against the color filter substrate 2 is small compared with resistance force of the seal 4 against the color filter substrate 2. Viscosity of liquid crystal 3 is in the order of 0.02 (Pa•s) and viscosity of an adhesive resin used as the seal 4 is in the order of several tens to several hundreds (Pa•s).

Since the deformation of the liquid crystal panel 20 proceeds in the center portion thereof at higher speed than that of the peripheral portion thereof, an inner surface of the color filter substrate 2 first reaches the display area spacers 16 arranged in the center portion. When the deformation further continues and the color filter substrate 2 becomes in pressure contact with the display area spacers 16, the progression of deformation is restricted by the resistance thereof. FIG. 2(b) shows this very state. In the state shown in FIG. 2(b), the display area spacers 16 arranged in the center portion was pressed down and, therefore, the cell gap in the center portion is smaller than the appropriate cell gap d0. This is because the initial size of the display area spacer 16 before compressed is set to the value equal to the appropriate cell gap d0. Further, since, in the state shown in FIG. 2(b), the vacuum portion 7 still exists and pressures inside and outside of the panel are not equilibrated (the inner pressure of the panel is different from atmospheric pressure), the deformation still further proceeds. This deformation proceeds in only the peripheral portion since the progression of deformation of the center portion is restricted by the resistance of the display area spacers 16 against the substrates 1 and 2.

[0011]

Thereafter, the deformation of the peripheral portion proceeds until the liquid crystal display panel 20 becomes in the state shown in FIG. 2(c). The

state shown in FIG. 2(c) shows a state in which the progression of deformation of the peripheral portion proceeds and finally the vacuum portion 7 disappears, so that the inner volume of the panel 20 becomes equal to the volume of liquid crystal 3, achieving the pressure equilibrium between the inside and the outside of the panel.

In the state shown in FIG. 2(c), the inner surface of the color filter substrate 2 is not in contact with the seal spacers 5. That is, the seal spacers 5 are not pinched between the substrates 1 and 2 and their function (function as the spacer) to maintain the gap between the substrates 1 and 2 at the appropriate value is not achieved enough.

Further, the inner surface of the color filter substrate 2 is not in contact with the display area spacers 16 arranged in the peripheral portion. That is, the display area spacers 16 arranged in the peripheral portion are not pinched between the substrates 1 and 2 and their function (function as the spacer) to maintain the gap between the substrates 1 and 2 at the appropriate value is not achieved and the gap in the peripheral portion does not reach the appropriate cell gap.

Therefore, as shown in FIG. 2(c), the cell gap value d1 of the center portion of the liquid crystal display panel 20 is smaller than the appropriate cell gap d0 ($d1 < d0$) and the cell gap value d3 of the peripheral portion thereof is larger than the appropriate cell gap d0 ($d3 > d0$), so that, between the center portion and the peripheral portion of the liquid crystal display panel, there is a portion in which the appropriate cell gap is obtained.

[0012]

As described above, the reason for the pressure equilibrium between the inside and the outside of the panel and the stoppage of progression of deformation in the state in which the cell gap is not uniform is that the amount of liquid crystal 3 is set to a value equal to the inside volume of the panel 20 in the state in which the cell gap is equal to the appropriate cell gap

d0 throughout the panel. That is, a portion of liquid crystal 3, which corresponds to the reduction of the cell gap from the appropriate cell gap value d0 in the center portion, is pushed into the peripheral portion, so that the cell gap in the peripheral portion becomes larger than the appropriate cell gap.

[0013]

The state shown in FIG. 2(c) is a metastable state and sustained for some period of time. If the hardening of the seal 4 were suspended for a considerably long time, the panel 20 could be deformed in a manner that the cell gap becomes uniform throughout the panel 20 due to the resistance of the display area spacers 16 in the center portion of the panel 20. However, when the seal 4 is left in unhardened state for a too long period of time under atmospheric pressure, there may be a case where the seal 4 is broken because pressure is directly applied to the seal 4 from the time when the panel 20 is put under atmospheric pressure. Therefore, a time period from the time when the panel is put in atmospheric pressure to the hardening time of the seal 4 is preferably from several minutes to several tens minutes. For this reason, the seal 4 has to be hardened under the condition in which the cell gap in the center portion of the panel is smaller than the appropriate cell gap and that in the peripheral portion is larger than the appropriate cell gap, as shown in FIG. 2(c).

The pressure acting on the seal 4 will be described with reference to FIG. 3. FIG.3 is a plan view of the TFT substrate after the seal printing and the dropping of liquid crystal are performed. There is a case where a closed curve shaped auxiliary seal 8 surrounding the seal 4 is formed as shown in FIG. 3. FIG. 3 shows a case where an area in which two liquid crystal display panels are included within a single auxiliary seal 8. The auxiliary seal 8 is used, after the substrates are adhered each other, to form and maintain a vacuum space between it and the seals 4 to enhance the pressing force to the

substrates under atmospheric pressure and maintain it.

Since the inner pressure of the seals 4 is increased with the progression of the above described deformation of the panels, the increased inner pressure is exerted on the inner surfaces of the seals 4.

When the auxiliary seal 8 is broken by atmospheric pressure, atmospheric pressure is exerted on the outer peripheral surface of the seal 4. Naturally, in the fabrication method without using the auxiliary seal 8, atmospheric pressure is exerted on the outer peripheral surface from a time when the panel is put under atmospheric pressure.

[0014]

As mentioned previously, in the liquid crystal injection method, liquid crystal is injected through an opening portion of a seal after the panel is assembled by adhering the substrates each other and hardening the seal. Therefore, even when the cell gap is smaller than the appropriate cell gap at the assembling step, it is possible to restore the appropriate cell gap by the resilient force of the spacers and the liquid crystal injecting step, since the seal has the opening portion. On the other hand, in the liquid crystal falling drop method, the cell gap is formed in the state where liquid crystal is sealed. Therefore, once the non-uniform cell gap is formed, it is difficult to restore the appropriate cell gap.

[0015]

As described above, in the conventional fabrication method of a liquid crystal display panel using the liquid crystal falling drop method, the cell gap of the liquid crystal display panel obtained becomes non-uniform since the cell gap in the center portion of the liquid crystal display panel is smaller and the cell gap in the peripheral portion is larger compared with the appropriate cell gap. Since, therefore, the display area spacers arranged in the peripheral portion of the liquid crystal display panel do not support the substrates, the liquid crystal display panel may be easily deformed by

external pressure and its weight, so that the uniformity of cell gap of the liquid crystal display panel can not be obtained. Moreover, since liquid crystal expands or contracts by variation of temperature and the amount of change of the cell gap in the center portion and in the peripheral portion is different, the display condition in the center portion of the liquid crystal display panel and the peripheral portion thereof becomes difficult.

As a result of these matters, the display quality of the liquid crystal display panel is degraded.

[0016]

The present invention was made in view of the above described problems of the conventional fabrication method of a liquid crystal display panel having a display area having spacers arranged, with using the liquid crystal falling drop method, and a problem of the present invention is to provide a fabrication method of a liquid crystal display panel, which has an appropriate cell gap throughout a display area thereof and is capable of avoiding inconvenience due to partial difference of deformation of the panel caused by difference in viscosity between a seal and liquid crystal and maintaining good display quality.

[0017]

[Means for Solving the Problem]

A first invention of this application for solving the above problem provides a fabrication method of a liquid crystal display panel having a pair of opposing transparent substrates adhered each other by a seal and liquid crystal sealed in a gap between the substrates and surrounded by the seal, including the steps of forming the seal on said transparent substrates such that the seal surrounds a display area of the transparent substrate, arranging spacers on the display area of the substrate, dropping liquid crystal onto an area surrounded by the seal on the transparent substrates, forming a panel by sticking one of the transparent substrates on the other

via the seal in a vacuum chamber, thereafter deforming the panel under atmospheric pressure by putting the panel under atmospheric pressure and, after a volume within said panel becomes equal to a volume of the liquid crystal, hardening the seal, characterized by that

the spacers have an initial size in a cell gap direction larger than an appropriate cell gap necessary to perform an appropriate liquid crystal display.

[0018]

The term “initial size” of the spacer here means a size in a free state having no influence of, particularly, compressive load, etc., exerted thereon and, when there is a variation in size of spacers, means an average size of the spacers used.

Since, therefore, the display area spacers having initial size or initial average size in the cell gap direction larger than the appropriate cell gap suitable for realizing an appropriate liquid crystal display are used in the fabrication method of the liquid crystal display panel of the first invention of this application, it is possible to prevent the spacers from being excessively collapsed to a size smaller than the appropriate cell gap due to atmospheric pressure exerted on the liquid crystal display panel, unlike the conventional spacers having initial size or initial average size equal to the appropriate cell gap. Therefore, it is possible to solve the problem of fabrication of a liquid crystal display panel having non-uniform cell gap in the center portion, which is smaller than the appropriate cell gap, and the cell gap in the peripheral portion, which is larger than the appropriate cell gap, at a time when the inner volume of the panel becomes equal to the volume of liquid crystal and the deformation of the liquid crystal display panel becomes in a metastable state, so that there is a merit that a liquid crystal display panel having uniform cell gap by relaxing the non-uniformity of cell gap in the peripheral portion is obtained.

Of course, there is a merit that a liquid crystal display panel having appropriate cell gap throughout a display area and providing good display quality is obtained by setting the amount of liquid crystal to an amount equal to the inner volume of the panel in the state where the cell gap becomes the appropriate cell gap throughout the display area of the liquid crystal display panel, as in the conventional method.

Further, since the display area spacers having initial size in the cell gap direction larger than the appropriate cell gap suitable for performing an appropriate liquid crystal display are used, the display area spacers in the display area are pressed between the transparent substrates to perform their function of restricting the cell gap to the appropriate value. As a result, there is a merit that the uniformity of cell gap is improved and maintained.

Incidentally, since the present invention requires the hardening of the seal after the volume of liquid crystal becomes equal to the inside volume of the panel, spacers, which are not compressed up to the appropriate cell gap by atmospheric pressure exerted on the panel (for example, spacers having initial size, which is too large compared with the appropriate cell gap or spacers, which are of a hard material and are substantially not deformed although the size is slightly larger than the appropriate cell gap) are not used in the present invention as the display area spacers. This is because, if such too large spacers or too hard spacers were used as the display area spacers, there would be an empty portion left in the panel and the inner volume of the panel does not become equal to the volume of liquid crystal in the panel. That is, in the present invention, the conditions of the display area spacer are set such that it can be compressed up to the appropriate cell gap by deformation under atmospheric pressure exerted on the panel.

[0019]

A second invention of this application is characterized by that, in the fabrication method of the liquid crystal display panel of the first invention of

this application, spacers, which are elastically deformed from the initial size or the initial average size to the appropriate cell gap, are used as the display area spacers.

[0020]

Since, according to the fabrication method of a liquid crystal display panel of the second invention of this application, spacers, which are elastically deformed from the initial size to the appropriate cell gap, are used as the display area spacers, there is a merit that it is easy to realize the deformation of the display area spacers from its initial size to the appropriate cell gap under atmospheric pressure.

Since, in the liquid crystal display panel fabricated according to the present invention, the display area spacers compressively deformed at room temperature are pinched between the substrates, there is a merit that the appropriate cell gap is maintained throughout the display area for a long time period. This is because, since the compressive stress (resistance force) acts on the whole panel, the whole panel has a structure, which is hardly deformed by external force. If the display area spacers were not pinched, there should be a possibility of movement of the display area spacers within the panel after the liquid crystal display panel is completed and, with such movement of the display area spacers, the display area spacers may be unevenly distributed and the function of the display area spacers for maintaining the cell gap may not be lost, resulting in that the cell gap becomes non-uniform.

It is preferable that spacers made of a resin material are used as the display area spacers, which are to be elastically deformed from the initial size to the appropriate cell gap.

[0021]

A third invention of this application is characterized by that, in the fabrication method of the liquid crystal display panel of the first invention or

the second invention of this application, the seal is mixed with spacers formed of a material, which is not deformed substantially when it is pinched between the substrates under atmospheric pressure.

[0022]

Therefore, according to the fabrication method of the liquid crystal display panel of the third invention of this application, there is a merit that the cell gap between the substrates in the seal portion of the liquid crystal display panel can be maintained highly precisely.

The size of the seal spacers in the cell gap direction in a state where the seal spacers are pinched between the substrates is set such that the cell gap in the display area becomes the appropriate cell gap.

Further, in order to make the seal spacers hardly deformable when they are pinched between the substrates under atmospheric pressure, a hard material such as glass or silica, etc., is preferably used as the seal spacers.

[0023]

[Mode for Carrying Out the Invention]

A fabrication method of a liquid crystal display panel according to an embodiment of the present invention will be described by using a TFT drive type color LCD panel, as an example, with reference to the drawings (TFT: Thin Film Transistor, LCD: Liquid crystal Display). It is a mere embodiment of the present invention and the present invention is not limited thereto.

[0024]

FIG. 1 is a typical cross section of a liquid crystal display panel 10 fabricated by the fabrication method of the present invention. This liquid crystal display panel 10 is a TFT drive type color LCD panel. As shown in FIG. 1, the liquid crystal display panel 10 is constructed with mainly a TFT substrate 1, a color filter substrate 2 opposing to the TFT substrate, liquid crystal 3 pinched between these substrates 1 and 2, a seal 4 for adhering the substrates 1 and 2 together and sealing liquid crystal 3, seal spacers 5 mixed

in the seal 4 and a display area spacers 6 arranged in a display area.

[0025]

An initial average size of the display area spacers 6 in a cell gap direction is set to a value equal to an appropriate cell gap value d0 to be achieved for appropriately performing a liquid crystal display. When the display area spacers are spherical or circular pillar shaped granulous spacers, the size thereof in the cell gap direction corresponds to a diameter thereof or, when it is a pillar shaped spacer, the size corresponds to a height thereof.

Conditions of the display area spacers 6 are set such that the display area spacers 6 can be compressively deformed to an appropriate cell gap under atmospheric pressure exerted on the panel 10.

Since these conditions of the spacers depend upon natures of the spacer (size of the spacer (height, cross sectional area, etc.), mechanical natures (elasticity, plasticity), etc.), the number of spacers per unit area on the transparent substrate (density of spacer existing on the transparent substrate), viscosity of the seal and viscosity of liquid crystal, etc., the conditions are preliminarily determined by calculations or experiments or both of them.

[0026]

Further, in this embodiment, resin spacers, which are elastically deformable from the initial size to the appropriate cell gap value d0, are used as the display area spacers 6.

Further, in this embodiment, glass spacers, which do not deformed substantially when they are pinched between the substrates 1 and 2 under atmospheric pressure, are used as the seal spacers 5.

[0027]

FIG. 1(a) shows a state immediately after liquid crystal 3 is dropped onto the TFT substrate 1, on which the seal 4 is formed and the display area

spacers 6 are arranged, the substrates 1 and 2 are adhered to each other within a vacuum chamber and the adhered substrates are put in atmosphere. In this state, an inside of the liquid crystal display panel 10 is a pressure (negative pressure) lower than atmospheric pressure and liquid crystal 3 does not fill an entire inside area of the liquid crystal display panel 10 completely as yet, a vacuum portion 7 being left. Thereafter, the liquid crystal display panel 10 is deformed due to a pressure difference between atmospheric pressure and the negative pressure within the panel in such a way that a distance between the TFT substrate 1 and the color filter substrate 2 is reduced. In FIG. 1, since the lower TFT substrate 1 is put on a horizontal plane, the color filter substrate 2 is deformed or moved. By this deformation or movement, liquid crystal 3 is pressed and gradually spread radially outward in a plane direction, so that the vacuum portion 7 is reduced gradually.

[0028]

However, the deformation of the liquid crystal display panel 10 proceeds in a center portion at higher speed than that in a peripheral portion as shown in FIG. 1(b). This is because, although atmospheric pressure exerted on the substrate is uniform, viscosity of liquid crystal 3 is very small compared with viscosity of the seal 4. That is, a resistance force of liquid crystal 3 against the color filter substrate 2 is small compared with a resistance force of the seal 4 against the color filter substrate 2. Viscosity of liquid crystal 3 is in the order of 0.02 (Pa•s) and viscosity of an adhesive resin used as the seal 4 is in the order of several tens to several hundreds (Pa•s).

[0029]

Since the deformation of the liquid crystal panel 10 proceeds in the center portion thereof at higher speed than that of the peripheral portion thereof, an inner surface of the color filter substrate 2 first reaches the

display area spacers 6 arranged in the center portion. The deformation further continues and, when the color filter substrate 2 becomes in pressure contact with the display area spacers 6, the progression of deformation is restricted by the resistance thereof. FIG. 1(b) shows this very state. In the state shown in FIG. 1(b), the display area spacers 6 arranged in the center portion was pressed down and, therefore, the cell gap in the center portion becomes substantially equal to the appropriate cell gap d0. This is because the initial average size of the display area spacer 6 in the cell gap direction is set to a value larger than the appropriate cell gap and the conditions of the display area spacers 6 are set such that the display area spacers 6 can be compressively deformed to the appropriate cell gap under atmospheric pressure exerted on the panel 10. Even if the cell gap in the center portion becomes a value smaller than the appropriate cell gap d0, the cell gap value does not become the minimum cell gap when the display area spacers having initial size in the cell gap direction equal to the appropriate cell gap are used, so that it is possible to limit the minimum cell gap to a value close to the appropriate cell gap d0.

Further, since, in the state shown in FIG. 1(b), the vacuum portion 7 still exists and pressures inside and outside of the panel are not equilibrated, the deformation still further proceeds. This deformation proceeds in only the peripheral portion. Since the progression of deformation of the center portion is restricted by the resistance of the display area spacers 6 against the substrates 1 and 2.

[0030]

Thereafter, the deformation of the peripheral portion proceeds as shown in FIG. 1(c) and the progression of deformation of the peripheral portion of the liquid crystal display panel 10 is restricted by the seal spacers 5. In the state shown in FIG. 1(c), the deformation of the peripheral portion and finally the inner surface of the color filter substrate 2 becomes in contact

with the seal spacers 5. In this case, since the seal spacers 5 formed of glass material is not substantially deformed, the gap between the substrates 1 and 2 is kept constant precisely.

Further, in the state shown in FIG. 1(c), on proceeds and finally the empty portion 7 disappears, so that the inner volume of the panel 20 becomes equal to the volume of liquid crystal 3, achieving the pressure equilibrium between the inside and the outside of the panel.

In the state shown in FIG. 2(c), the display area spacers 6 arranged in the peripheral portion are pinched between the substrates 1 and 2 and compressively deformed, so that they provide a cell gap substantially equal to the appropriate cell gap d0. That is, the cell gap in the peripheral portion reaches the appropriate cell gap d0 substantially.

Further, the inner pressure is increased by collapse of liquid crystal 3 in the peripheral portion. Therefore, when the cell gap of the center portion reaches a value smaller than the appropriate cell gap d0 in the state shown in FIG. 1(b), the cell gap value in the center portion is recovered to the appropriate cell gap d0.

Even when there are portions having the cell gap slightly larger than the appropriate cell gap d0, fine voids (not shown) exist in the panel 10 and the inner pressure of the panel 10 is not equal to atmospheric pressure as yet since the amount of liquid crystal 3 is set equal to the inner volume of the panel 10 in the state where the cell gap becomes equal to the appropriate cell gap d0 throughout the display area. That is, since the inside pressure of the panel 10 is negative, the panel 10 is gradually deformed toward the appropriate cell gap d0 until the inner volume of the panel 10 becomes equal to the volume of liquid crystal 3 throughout the display area.

As a result, liquid crystal 3 spreads over the whole area of the panel 10 with uniform thickness, the voids disappear and the inner and outer pressures of the panel 10 equilibrates, resulting in the liquid crystal display

panel 10 having the appropriate cell gap d0 throughout the display area thereof. According to this liquid crystal display panel 10, it is possible to obtain a high display quality.

The seal 4 is hardened, next. When ultraviolet ray setting adhesive is used for the seal 4, the seal 4 can be hardened by irradiating ultraviolet ray. When thermosetting adhesive is used for the seal 4, the seal 4 can be hardened by, for example, heating it at about 120°C for 1 hour or longer.

Thereafter, an outer configuration of the panel is cut apart and the liquid crystal display panel is completed by, for example, attaching polarizing plates to a front and rear surfaces thereof, respectively.

[0031]

According to this embodiment, the problem of the conventional method that the inner surface of the color filter substrate 2 is not in contact with the seal spacer 5 having initial size equal to the appropriate cell gap in the cell gap direction when the inner and outer pressures of the panel equilibrates and the seal spacer does not function as spacer is excluded, and the seal spacers 5 are pinched between the substrates 1 and 2 and sufficiently functions (function as the spacer) to maintain the gap between the substrates 1 and 2 and restrict it to an appropriate value.

Further, the inner surface of the color filter substrate 2 is in pressure contact with the display area spacers 6 arranged in the peripheral portion, so that the spacers function (function as the spacer) to maintain the gap between the substrates 1 and 2 and to restrict it to an appropriate value.

[0032]

[Experimental Example]

Experiments conducted by the inventors of this invention for determining the conditions of the display area spacers 6 required to compressively deform the display area spacers 6 to the appropriate cell gap by atmospheric pressure exerted on the panel 10 and obtain the appropriate

cell gap throughout the display area will be described.

[Content of the Experiments]

The spherical display area spacers 6 each having diameter of 6.0 μm as initial average size were dispersed and the appropriate cell gap value d0 was controlled by controlling a dropping amount of liquid crystal 3. The relative value of the initial average size against the appropriate cell gap d0 (6.0/d0) was calculated. The state of the liquid crystal display panel was tested. Two experiments were performed. In the first experiment, viscosity of the seal 4 was about 200 (Pa•s) and, in the second experiment, it was about 300 (Pa•s). Conditions of the experiments are disclosed below.

[Conditions of Experiments] Conditions of the experiments are disclosed below.

(Condition 1) Conditions used in the embodiment were used.

(Condition 2) The auxiliary seal 8 shown in FIG. 3 was used.

(Condition 3) Configuration of each display area spacer 6 was spherical, material thereof was resin, diameter thereof was 6.0 μm and dispersing density was 200 to 250 spacers/mm^2.

Test results of elasticity characteristics of the display area spacers 6 are shown below. In a case where diameter is 4.5 μm and dispersing density is 200 to 250 spacers/mm^2, (deformation amount μm, load mN) = (0.1, 0.83), (0.2, 1.82), (0.3, 2.96), (0.4, 4.26), (0.5, 5.71).

(Condition 4) A ultraviolet ray setting adhesive is used as the material of both the seal 4 and the auxiliary seal 8 and viscosity of the ultraviolet ray setting adhesive is about 300 (Pa•s) in the first experiment and about 300 (Pa•s) in the second experiment..

(Condition 5) The material of the seal spacer 5 is glass, configuration is spherical and diameter is 6.0μm.

(Condition 6) Viscosity of liquid crystal 3 is 0.018 to 0.02 (Pa•s).

[0033]

[Result and Verification of the Experiments] Result and verification of the experiments are disclosed below.

[0034]

First Experiment (seal viscosity: 200 (Pa•s))

① (d0, 6.0/d0) = (5.73, 104.6 %) Voids were left within the panel. This was due to that the initial size of the display area spacer 6 was large with respect to d0. It is necessary to reduce the initial size of the display area spacers 6 relatively.

② (d0, 6.0/d0) = (5.94, 100.9 %) Cracks were found in the peripheral surface of the seal 4. This was due to that the seal 4 was urged from the inside to outside of the panel 10. It is necessary to increase the initial size of the display area spacers 6 relatively.

③ (d0, 6.0/d0) = (5.94, 100.6 %) Cracks were found in the peripheral surface of the seal 4. This was due to that the seal 4 was urged from the inside to outside of the panel 10. It is necessary to increase the initial size of the display area spacers 6 relatively.

④ (d0, 6.0/d0) = (5.76, 104.1 %) Voids were left within the panel. This was due to that the initial size of the display area spacers 6 was large with respect to d0. It is necessary to reduce the initial size of the display area spacers 6 relatively.

[0035]

Second Experiment (seal viscosity: 300 (Pa•s))

⑤ (d0, 6.0/d0) = (5.99, 100.0 %) The seal 4 was urged from the inside to outside of the panel 10, and a portion of the seal 4 was broken and liquid crystal 3 leaked out to a region between the seal 4 and the auxiliary seal 8. This was due to that the initial size of the display area spacers 6 was small with respect to the initial size d0 of the display area spacers 6. It is necessary to increase the initial size of the display area spacers 6 relatively.

⑥ (d0, 6.0/d0) = (5.83, 102.9 %) Cracks were found in the peripheral

surface of the seal 4. This was due to that the seal 4 was urged from the inside to outside of the panel 10. It is necessary to increase the initial size of the display area spacers 6 relatively.

⑦ (d0, 6.0/d0) = (5.72, 104.9%) No defect was found.

⑧ (d0, 6.0/d0) = (5.61, 107.0%) Unevenness of cell gap was found. This was due to that the initial size of the display area spacers 6 was slightly large with respect to d0. It is necessary to increase the initial size of the display area spacers 6.

⑨ (d0, 6.0/d0) = (5.50, 109.1%) Unevenness of cell gap was found. This was due to that the initial size of the display area spacers 6 was slightly large with respect to d0. It is necessary to increase the initial size of the display area spacers 6.

[0036]

From the above results, it was possible to presume in the first experiment that the optimal relative value of the initial average size with respect to the appropriate cell gap value is about 102%.

Viscosity of the seal 4 was about 200 (Pa•s) in the first experiment and was about 300 (Pa•s) in the second experiment. Therefore, from the above mentioned results, it was possible to confirm that the larger initial size of the display area spacer 6 in the cell gap direction is required for the larger viscosity of the seal 4.

[0037]

From the above experiments, it is possible to determine the conditions of the display area spacers 6, which are to be set in order to obtain the appropriate cell gap throughout the display area, by compressively deforming the display area spacers 6 to the appropriate cell gap by atmospheric pressure exerted on the panel 10.

[0038]

[Advantage of the Invention]

As described hereinbefore, since the present invention uses the display area spacers having an initial average size in the cell gap direction larger than the appropriate cell gap required to perform a liquid crystal display appropriately, it is possible to solve the problem of non-uniformity of the cell gap to thereby provide a liquid crystal display panel having the appropriate cell gap throughout the display area thereof and capable of providing a high display quality.

Further, since, in the liquid crystal display panel fabricated by the present invention, the display area spacers in the state in which the spacers are compressively deformed at normal temperature, are pinched between the substrates, there is an advantage that the structure of the whole panel is hardly deformed by the compressive stress (resistance force) of the display area spacers and the appropriate cell gap can be maintained in the whole display area for a long period of time.

[Brief Description of the Drawings]

[FIG. 1] A typical cross sectional view of a liquid crystal display panel 10 fabricated by the fabrication method of the present invention.

[FIG. 2] A typical cross sectional view of a liquid crystal display panel 20 fabricated by the conventional fabrication method.

[FIG. 3] A plan view of a TFT substrate after the seal printing and liquid crystal dropping.

[Description of Reference Numerals]

1 ... TFT substrate

2 ... color filter substrate

3 ... liquid crystal

4 ... seal

5 ... seal spacer

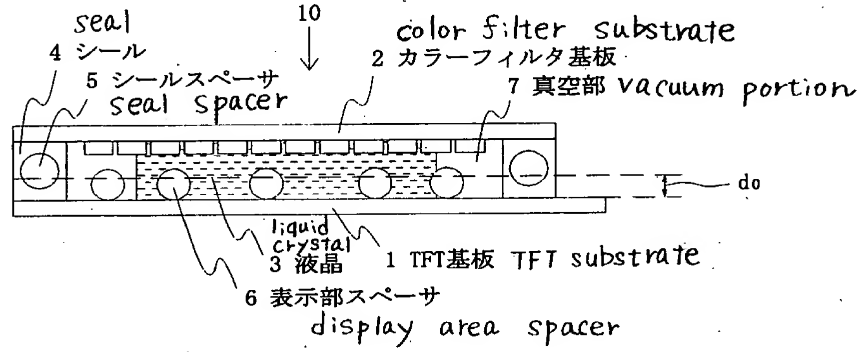
6, 16 ... display area spacer

7 ... vacuum portion

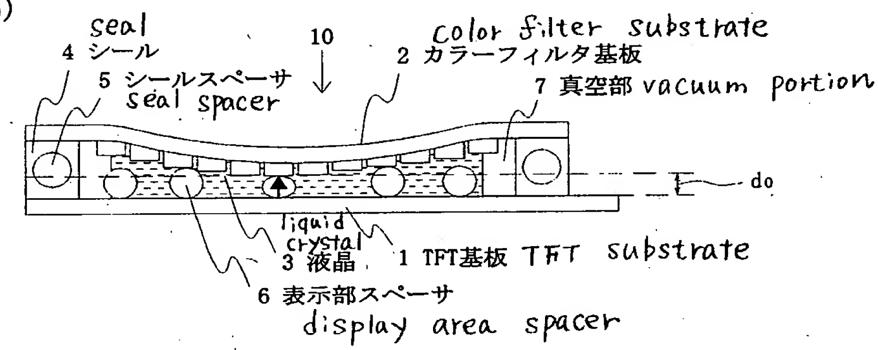
8 ... auxiliary seal

【書類名】　図面
[Designation of Document]　Drawings
【図１】
[FIG.1]

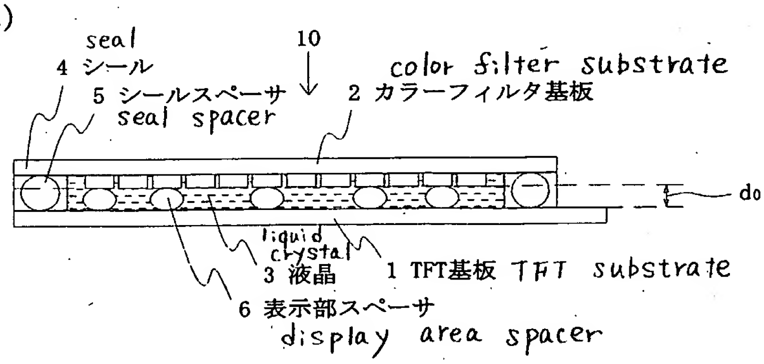
(a)



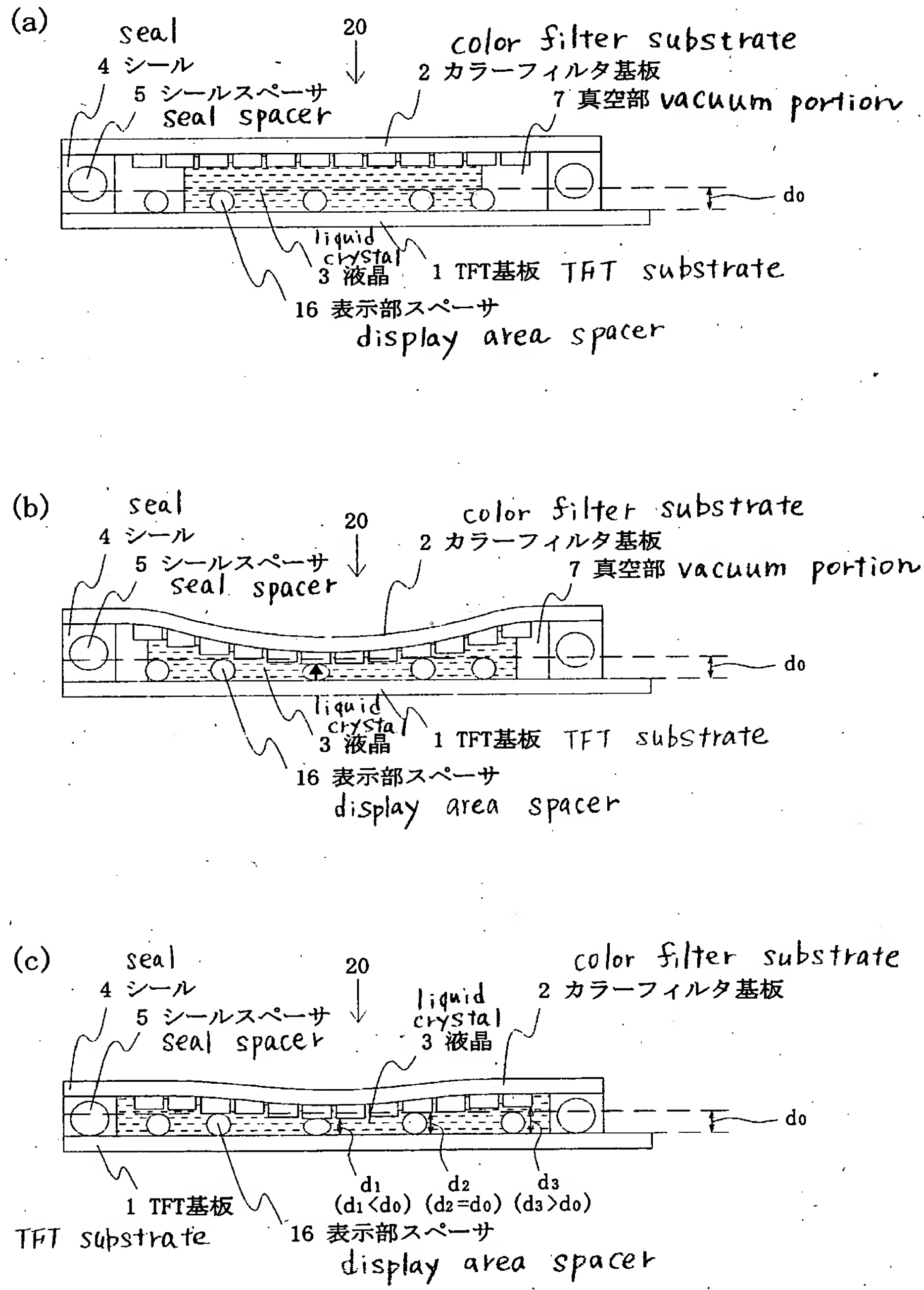
(b)



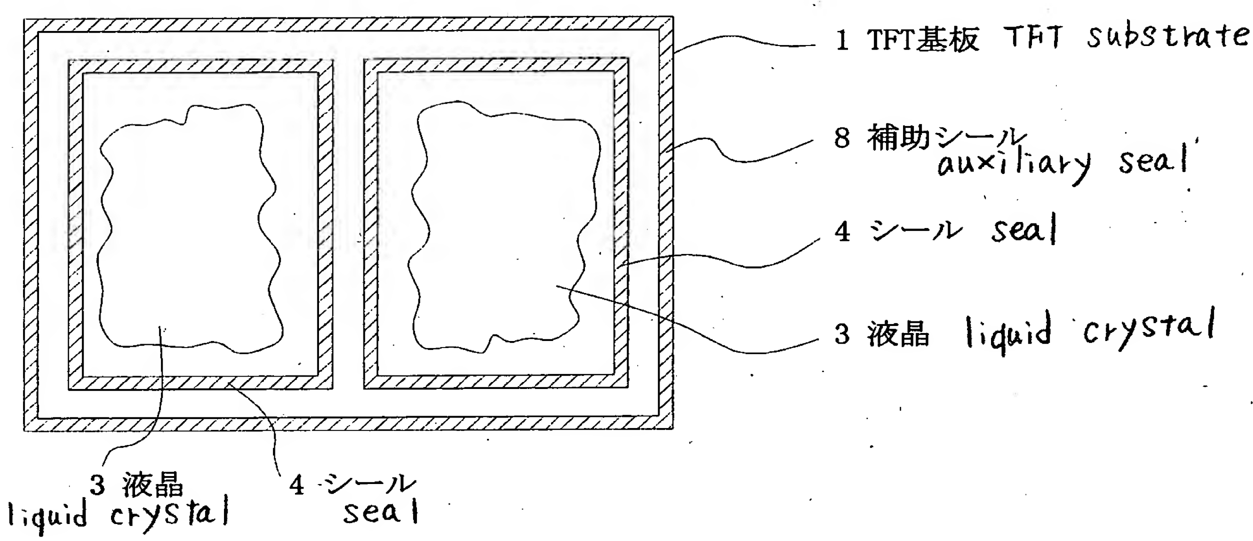
(c)



【図２】
[FIG.2]


(a)
seal
4 シール
5 シールスペーサ
seal spacer
20
color filter substrate
2 カラーフィルタ基板
7 真空部 vacuum portion
do
liquid crystal
3 液晶
1 TFT基板 TFT substrate
16 表示部スペーサ
display area spacer
(b)
seal
4 シール
5 シールスペーサ
seal spacer
20
color filter substrate
2 カラーフィルタ基板
7 真空部 vacuum portion
do
liquid crystal
3 液晶
1 TFT基板 TFT substrate
16 表示部スペーサ
display area spacer
(c)
seal
4 シール
5 シールスペーサ
seal spacer
20
liquid crystal
3 液晶
color filter substrate
2 カラーフィルタ基板
do
1 TFT基板
TFT substrate
d1 (d1<do)
d2 (d2=do)
d3 (d3>do)
16 表示部スペーサ
display area spacer

【図３】
[FIG. 3]


1 TFT基板 TFT substrate
8 補助シール auxiliary seal
4 シール seal
3 液晶 liquid crystal
3 液晶 liquid crystal
4 シール seal

[Designation of Document] Abstract

[Abstract]

[Problems] In a fabrication method of a liquid crystal display panel having spacers arranged in a display area, with using a liquid crystal falling drop method, to provide an appropriate cell gap throughout a display area and maintain a good display quality, by avoiding a problem resulting from partially different deformation of the panel due to difference in viscosity between a seal and liquid crystal.

[Means for Solving the Problems] As the display area spacers 6, elastic spacers of resin, etc., having an initial size in a cell gap direction larger than an appropriate cell gap d0 to be formed in order to perform an appropriate liquid crystal display are used. An excess deformation of the cell gap to a value smaller than the appropriate cell gap after the panel is put under atmospheric pressure is restricted by resistance force of the display area spacers 6 (FIG. 1(b)) . As a seal spacer 5, a spacer formed of a material such as glass, etc., which is not deformed substantially when pinched between substrates 1 and 2 under atmospheric pressure, is used.

[Figure to be Selected] FIG. 1